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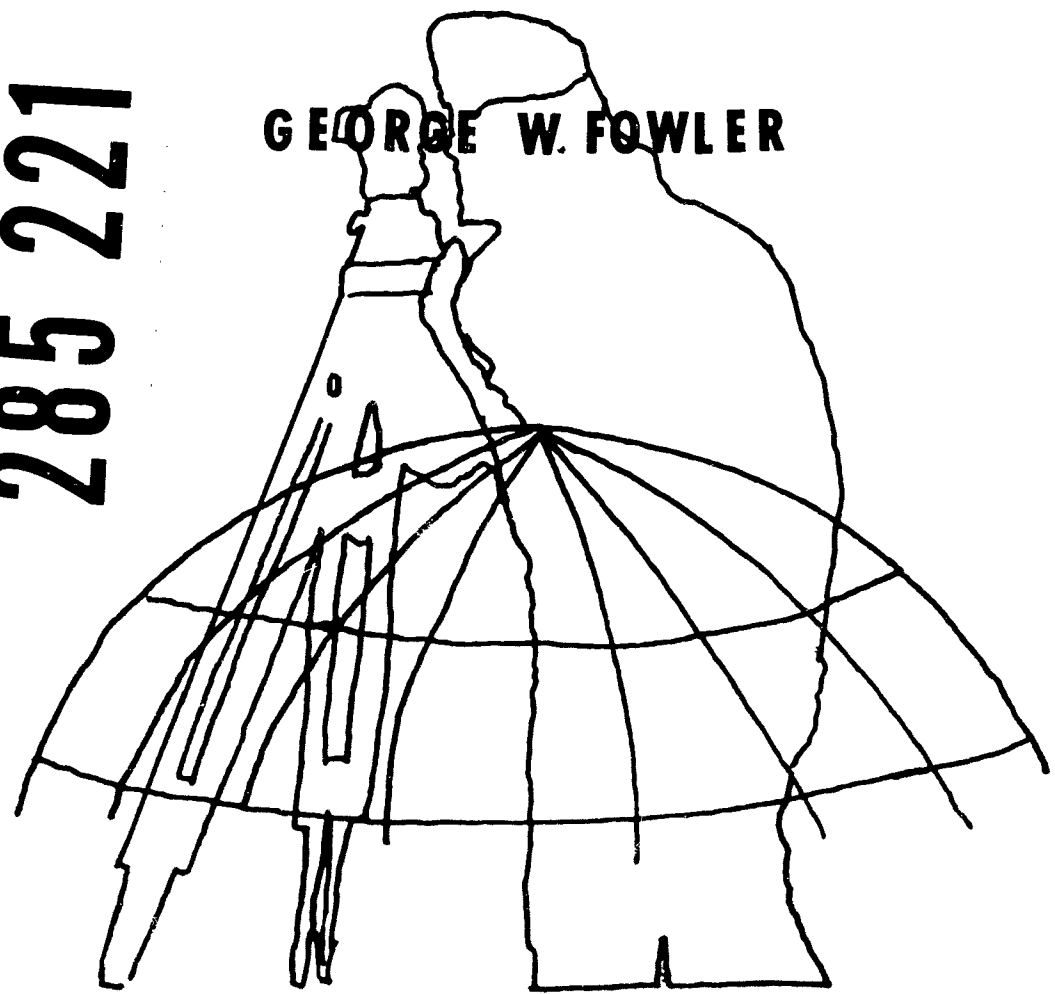
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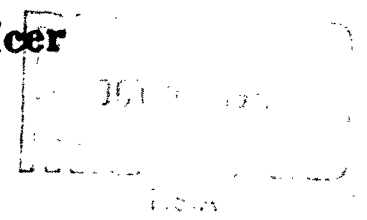
TRAVERSE NAVIGATION IN POLAR REGIONS

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PREFACE

"Small fissures were passed over and visible crevasses were skirted. We were passing over a suspected crevassed area but received little or no reading on the detector [electronic crevasse detector]. Suddenly just in front of the second Weasel, a large portion of a snow bridge dropped; there was no warning. Both vehicles were stopped on the cornice of a huge crevasse. We carefully evacuated the Weasels and with utmost caution began probing."

This is an extract from the Chief Navigator's Log "Operation Lead Dog", Greenland 1959.

Continuing:

"We were in quite a predicament—a Weasel on each side of a large crevasse, each resting on a bridge of rotten ice. We carefully moved the Weasels to safer ice and by probing found the strongest bridge across the crevasse. We turned the crevasse detector [Weasel] around on a small ridge of solid ice. The driver started the vehicle across the crevasse in first gear, low range, and then rode on the outside, ready to abandon the vehicle should it fall in. Luckily everything was O.K. Using the same technique of crossing by vehicle, combined with probing on foot, we managed to work our way out of the crevasse field without further incident."

Negotiating crevasse fields is one of the hazards confronting the traverse navigator in polar regions. These high latitudes present various problems. Season of operation, extremes of altitude and temperature, directive force of the earth's rotation, and surface irregularities all strike at the heart of normal navigational procedures.

No single definition of the geographic limits of the polar regions satisfies the needs of all who are interested in these areas. Astronomically, the parallels of latitude at which the sun becomes circumpolar are considered the lower limits.

Basically, navigation on land combines the same elements as navigation at sea: dead reckoning, piloting, electronic navigation, and celestial navigation. However, a considerable amount of ingenuity is needed to adapt available equipment or to improvise a suitable piece of equipment to meet a particular need. As man continues to press back the frontiers in this pristine environment, his demand of the present will become a guide to further refinement in the future.

A combination of dead reckoning and celestial navigation provided the basis for traverse navigation. Dead reckoning involves measurement of direction and distance traveled. Celestial navigation is the use of sighting on celestial bodies to find one's position. This is based on the relationship which exists among three sets of coordinates: the terrestrial coordinates (latitude and longitude); the celestial coordinates (declination and right ascension); and the interconnecting coordinates (altitude, azimuth, and hour angle).

Before venturing into the polar regions, which constitute high latitudes of the globe, a sound basic knowledge of the fundamentals of navigation is mandatory. The prudent navigator should acquaint himself with the experiences of others who have traveled in these areas.

This paper is not intended to be used as a text for traverse navigation, but rather to furnish information and knowledge, collected through experience by the writer.

Detailed information on any specific technique used in traverse navigation may be obtained upon written request.

TRAVERSE NAVIGATION IN POLAR REGIONS

Polar navigation, necessary for successful movements, is an art subject to the problems common to the polar regions in general, and in addition, the peculiarities of the regions themselves. These vast, mysterious, ice-locked areas are relatively inaccessible because of their severe climates and remoteness. Throughout the decades they have presented specific problems and navigational difficulties, many of which have yet to be resolved. As a result there is a continuing need for exploratory missions and vigorous programs for development of polar navigational equipment and techniques.

Any purposeful movement in the universe involves an intention to proceed to a definite point, and navigation is the business of proceeding in such a manner as to arrive at that point. The primary function of navigation is the determination of what direction to take to accomplish an intended movement. Locating positions and measuring distance and time are means of performing this function.

Basically, navigation in polar regions does not differ from navigation in other latitudes except for some alterations necessitated by unique conditions. A knowledge of these conditions and why they exist should be mastered by anyone who intends to venture into high latitudes.

1. Problems of High Latitude Navigation:

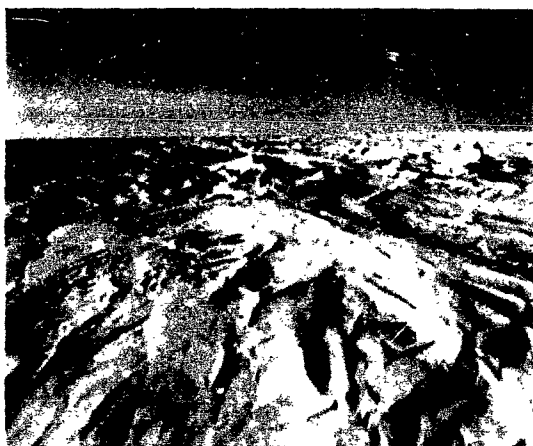
a. Travel on the Ross Ice Shelf, Antarctic Plateau, and the Greenland Icecap is analogous in many ways to travel on the open sea. For hundreds of miles the terrain is a featureless, frozen sea. Navigating through marginal areas is not a matter of taking bearings from recognizable landmarks plotted on a chart, for current charts of these areas are not sufficiently distinctive one from the other to make good navigation landmarks. Finally, the constant hazard of crevasses must be fully taken into account in navigational operations.

b. The polar navigator has no periods of darkness during the season when most operations take place and therefore cannot make use of stars for celestial navigation. For more than a four-month period all his fixes must depend on the sun.

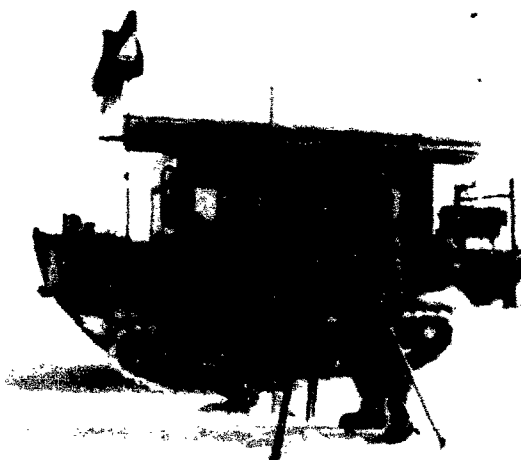
c. Keeping accurate time is a difficult problem in the polar regions. The extremes of temperature and of altitude variations cause chronometers to be relatively unreliable, and radio time checks are difficult to obtain due to ionospheric disturbances, commonly known as magnetic storms or radio blackout.



Nunataks



Heavy Sastrugi



Establishing a new trail

d. Since longitude lines are so close together in the polar regions, time zones become practically useless, and the rapid convergence of meridians makes plotting of courses by rhumb lines subject to great error unless extreme care is taken. Course plotting by rhumb lines necessitates constant compensation for convergence. However, a relatively simple equation for computing this convergence has been developed and proven sufficiently reliable for high latitude navigation.

$$a = \lambda \times \sin \phi_m$$

where

a = convergence in seconds

λ = difference in longitude

ϕ_m = mean of starting and ending latitude

e. The magnetic compass is erratic and completely unreliable. Even the gyro compass, which depends on the rotation of the earth for its directive force, becomes less accurate in the polar areas since this directive force approaches zero at the poles.

2. Traverse Navigation

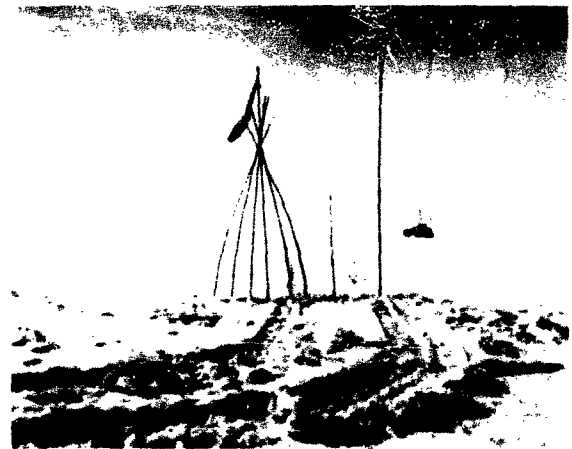
a. Course Plotting. Because of the rapid convergence of the meridians in polar regions, the true direction of an oblique course near the pole may vary considerably over a relatively short distance. As the meridians are actually radials meeting at the poles, instead of being parallel as they appear on the familiar Mercator Chart, the Polar Grid System of Navigation is employed using the Polar Stereographic Projection Chart.

In using grid navigation, one should keep clearly in mind the fact that the grid lines are parallel on the chart, and that only on the Transverse Mercator and Polar Gnomonic Projections do the grid lines have geographic significance.

b. Trail Azimuths. In establishing the traverse courses, the following procedure is used. Astronomic azimuths are determined by observing the angle between a mark and the sun. The computation consists of calculating the azimuth of the celestial body at the time of observation, then subtracting the measured angle from this value to obtain the azimuth of the mark. The calculation of the azimuth of the sun involves the solution of the spherical triangle whose vertices are the pole, the observer's zenith, and the body observed.

c. Trail Marking. Dead reckoning (D.R.) involves measurement of direction and distance traveled. Course direction is maintained on the traverse by back sighting on the poles set up in marking the trail. This method has been found to be more reliable than attempting to use any type of compass. The heading desired is obtained by a series of sun azimuths using this precision instrument. The poles are placed every $\frac{1}{4}$ mile and subsequent poles are placed at this interval by back sighting on previously placed poles, using binoculars. Trail azimuths are taken frequently (about every 25 miles if weather permits) to check alignment, and a fix is made about every 50 miles. In this way, a course can be maintained to within 0.5° . A problem arises with this method in periods of low visibility. Movement must be stopped if two poles to the rear cannot be seen. The above system has proven adequate only for temporary marking of trails (1 or 2 years) over regions permanently covered with ice and snow.

d. Distance. The principal means of keeping distance on the traverse is by using the vehicle odometer. This is more practical than attempting to compute distance from speed and time because speed varies greatly on traverses. Since the odometer records in statute miles, this reading must be converted to nautical miles, the unit required for plotting. Distance error caused by the vehicle not traveling in a straight line or moving over uneven terrain is not great; fixes with the theodolite every 50 miles show an error of not more than $\frac{1}{4}$ mile or 1 per cent, and this allows for the error in the odometer itself.



600-mile trail marker with snow accumulation stake. Byrd-South Pole Traverse.



Probing a crevasse

e. Celestial Observations.

Celestial navigation is the use of sightings on celestial bodies to determine a geographic position. This is based on the relations which exist among three sets of coordinates: the terrestrial coordinates (latitude and longitude): the celestial coordinates (declination and right ascension): and the interconnecting coordinates (altitude, azimuth, and hour angle).

f. Sight Reduction. There

are many methods of sight reduction. However, for field work this writer prefers the method set forth in H.O. Pub.

No. 214¹. For requirements that demand accurate positions in polar regions, a method has been developed by the writer and Sergeant Busby M. Winn, of the U.S. Army Transportation Board. This method was used in establishing the geographic location of the east end of the Horlick Mountain Range, Antarctic, and also was used on the Greenland Icecap.




Weasel (M29C) in heavy sastrugi



Crevasse detector

¹U.S. Navy Hydrographic Office, Tables of Computed Altitudes and Azimuths (Washington: Government Printing Office, 1952) VIII - IX



East end Horlick Mountain Range position determined
by Astro observations and triangulation.

FWLER-WINN METHOD OF FINAL REFINEMENT OF POSITION

Method of Observation. Astro observations are made at predetermined times; namely, when the sun is on the observer's meridian and the prime vertical. Three sets of three observations each are observed at each point and then averaged. This results in one strong L.O.P. (Line of Position) in each of the four quadrants: two for latitude and two for longitude. This set of sights gives a square instead of the triangle normally used. Bi-quadrant sights may be observed for assisting in the final position evaluation. The strongest L.O.P.'s are then evaluated and the position within the square is located.

Method of Computation. All observations are first computed by the H.O.-214 method. The result of this sight reduction, when plotted, becomes the A.P. (Assumed Position). The following equations are then applied using this A.P.

The height computed is expressed by the equation:

$$\sin HC = \sin \phi \sin \sigma + \cos \phi \cos \sigma \cos "t"$$

where

HC = Height computed

ϕ = Assumed latitude

δ = Declination

"t" = Meridian angle

The sun azimuth is determined by the formula:

$$\sin A = \frac{\cos \delta \sin "t"}{\cos HO}$$

where

A = Azimuth

HO = Height observed

δ = Declination

"t" = Meridian angle

Determination of Error. To determine the most probable error for any one observation or total probable error for two or more observations, the following method is employed: The square root of the sum of the squares of the residual multiplied by a factor computed by Bessels formula.

$$\frac{.6756}{n(n-1)}$$

where

n = Number of observations

This will indicate the most probable error in tenths of seconds.

SUMMARY

Traverse navigation in high latitudes is an art in itself, subject to peculiarities of individual areas and to the unique characteristics

of polar regions in general. The navigator must think in terms of specialized navigation techniques and equipment, developed through research on the effects of astronomic, cartographic, and magnetic conditions.

Polar regions present various problems. Season of operation, extremes of altitude and temperature, directive force of the earth's rotation, and surface irregularities all strike at the heart of normal navigational procedures. Course plotting by rhumb lines necessitates constant compensation for the rapid convergence of meridians.

A combination of dead reckoning and celestial navigation provides the basis for traverse navigation. Dead reckoning involves measurement of direction and distance traveled. Celestial navigation is the use of sightings on celestial bodies to find one's position. This is based on the relationships which exists among three sets of coordinates: the terrestrial coordinates (latitude and longitude); the celestial coordinates (declination and right ascension); and the interconnecting coordinates (altitude, azimuth, and hour angle). For requirements that demand accurate positions in polar regions, a refined method has been developed; namely, the Fowler-Winn Method of Final Refinement of Position.

NOTES ABOUT THE AUTHOR

The author, CWO-W3 George W. Fowler, is presently assigned to the staff of the U.S. Antarctic Projects Office.

He has participated in Operation DEEP FREEZE 60, 61, and 62 as Chief Navigator (surface) to Navy Task Force 43, Antarctica. His duties include long range aerial reconnaissance for mapping and astro identification purposes and extended surface exploratory and scientific traverses.

Mr. Fowler has participated in over eleven major expeditions in Greenland, Canada, Polar Basin, and Antarctica, either as chief navigator or in an observer status. These expeditions include:

Wintering over Party, Thule, Greenland 1956-1957 Mr. Fowler was the navigator of heavy swings during the winter months and in addition was O.I.C. for air force rescue missions on the ice cap.

Operation KING DOG - 1958 This was an expedition conducted from Sonderstrom, Greenland to a point approximately 100 miles west for purposes of finding an access route from the land area onto the icecap.

Operation LEAD DOG - 1958 This heavy swing from Thule, Greenland into Nyeboe Land and Peary-Walcott Land and return covered a distance of 1,600 miles round trip. The objectives were exploration, testing of polar equipment and the accumulation of scientific data.

Operation TOP DOG 1959-1960 The 1959 operation was aerial reconnaissance and ice studies of Baffin Bay. In 1960 an expedition utilizing vehicles was mounted from Thule, Greenland north over Baffin Bay for the study of traffic ability on ice and the collection of scientific data.

Operation POLE HOP - 1960 This was a test and evaluation of the Doppler Navigation System in army aircraft. This operation took place at Station Alert, Ward Hunt Island and Ellsmere Island in northwest Canada.

Operation DEEP FREEZE 1959-1960 The author was Chief Navigator with U.S. Navy Task Force 43 in Antarctica for topographic survey of the Hut Point on McMurdo Sound.

Operation DEEP FREEZE 1960-1961 The author was Chief Navigator with U.S. Navy Task Force 43 in Antarctica for the heavy swing conducted from Byrd Station to the South Pole.

Liaison with U.S. Polar Research and Development Command The author served as an observer of tests of trail marking systems at Thule, Greenland.

Operation DEEP FREEZE 1961-1962 Author was Chief Navigator with U.S. Navy Task Force 43 for the Little America V - Byrd Station Traverse.